DOCUMENT RESUME

ED 240 424 CG 017 253

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TITLE Aging and the Semantic Priming of Lexical Decisions.
SPONS AGENCY National Inst. on Aging (DHHS/NIH), Bethesda, MD.
PUB DATE Aug 83
NOTE 20p.; Paper presented at the Annual Convention of the American Psychological Association (91st, Anaheim, CA, August 26-30, 1983).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Age Differences; *Aging (Individuals); *Cognitive Processes; Language Patterns; *Long Term Memory; Networks; Older Adults; *Semantics; Young Adults
IDENTIFIERS Automatic Language Processing; Effort; *Semantic Priming

ABSTRACT

Research on the cognitive processes used in semantic priming has shown that the processing of a given stimulus is speeded by prior processing of a related stimulus as the result of automatic and/or effortful priming. To investigate the effect of age on semantic priming, two independent studies were conducted at Pomona College in California and at Georgetown University in Washington, D.C. In the Pomona study, 64 adults (32 young adults, 32 older adults) decided whether or not a visually presented sequence of letters (target) was a word after being shown a prime. Semantic relatedness, participant expectations for the target, and stimulus onset asynchrony (SOA), i.e., the interval between the onset of the prime and the onset of the target, served as independent variables. An analysis of the results showed no evidence that older adults have a more limited ability to switch attention, or that they require more time than younger adults to do so. No age differences in the effortful components of semantic priming, nor in automatic priming at the 410 msecond stimulus onset were found. In the Georgetown study, 108 adults made decisions on target words after being shown a prime, similar to the Pomona study. The stimulus onset was varied between subjects. An analysis of the results showed that, as in the Pomona study, no age differences in priming occurred at stimulus onsets of 450 and 1000 mseconds. However, at 150 mseconds, age differences in automatic semantic priming did occur, with younger adults showing significantly more effect. (BL)

ED240424

AGING AND THE SEMANTIC PRIMING OF LEXICAL DECISIONS

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Paper presented at the Annual Conference of the American Psychological Association, Anaheim, CA, August 26-30, 1983.

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This presentation is unusual in that it combines work conducted independently by investigators who have met face-to-face only once. Deborah Burke's research was carried out at Pomona College in Claremont, California, and mine at Georgetown University in Washington, D. C. After each of us had begun our projects, we discovered that we were approaching related questions using similar techniques. This symposium offered a welcome opportunity to present our work together. The fact that the studies were conducted independently might have been a disadvantage, since the Pomona and Georgetown experiments differ in many ways including instructions to the participants, stimuli, and details of method. Fortunately, though, our results complement each other nicely, so these methodological differences only increase the generality of our findings.

Our research is concerned with the phenomenon of <u>semantic priming</u>, which refers to the fact that the processing of a given stimulus is speeded by prior processing of a semantically related stimulus: For example, the word ELM is recognized or named more quickly if it follows the word TREE than if it follows the word VEGETABLE. Semantic priming is best explained by network theories (e.g, Collins & Loftus, 1975; Anderson, 1976) which assume that long-term memory consists of a semantically organized network of concept nodes

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* This paper was presented as part of a symposium entitled "New Directions in Research on Automatic and Effortful Processing" at the annual meetings of the American Psychological Association, Anaheim, August 1983. This research was supported by National Institute on Aging grants to Darlene V. Howard and Deborah M. Burke. Please contact the authors at the following addresses to obtain technical reports containing more detailed presentations of this work. Darlene V. Howard, Department of Psychology, Georgetown University, Washington, D. C. 20057. Deborah M. Burke, Department of Psychology, Pomona College, Claremont, California 91711.

interconnected by labeled relations. When a stimulus such as TREE is encountered, its corresponding concept node is assumed to be activated temporarily, and activation spreads through the network, priming related nodes such as ELM, rendering them more accessible.

Semantic priming is believed to be the result of two kinds of processes, one automatic and the other effortful (e.g., Posner & Snyder, 1975; Posner, 1978). The characteristics of each kind of priming are summarized in the top part of Table 1. Automatic priming spreads from the prime node to nearby, semantically related nodes. It occurs inevitably as a result of processing the prime, so it is outside the conscious control of the individual. Furthermore, it has a very short latency and is unlimited in capacity, so that it does not interfere with other processes. In contrast, effortful priming requires that the individual direct attention to concept nodes corresponding to items that are likely to occur next. Not only is such effortful activation under the control of the individual, but it has a longer latency since some time is required to switch attention, and it has a limited capacity. That is, when attention is directed to expected nodes, the processing of unexpected stimuli is inhibited.

Thus, according to two-process theories, TREE primes ELM for one or both of two reasons. First, activation spreads automatically from the node for TREE to the node for the related concept ELM. Second, if people expect related words to occur together, then upon seeing TREE they direct their attention voluntarily to nodes corresponding to related words such as ELM.

It is important to determine whether semantic priming is age-sensitive, because it underlies the encoding and retrieval processes involved in remembering, thinking, and processing language. While earlier research (e.g., Cerella, Poon, & Fozard, In press; Clark, 1981; Howard, McAndrews, & Lasaga,

1981) has suggested that se priming is constant across the adult lifespan, these studies hav separated the automatic from the effortful components of priming. Hasher & (1979) hypothesized that effortful, but not automatic, processes will ge with age, because older adults have reduced attentional capacity. The research we will report here tests this hypothesis by using several methods to differentiate the automatic from the effortful components of priming.

All of the research we will discuss has used a *lexical decision task* in which the participant decides whether a visually presented sequence of letters is a word. On each trial a *prime*, to which the person need not respond overtly, is followed by a *target*, for a lexical decision. Participants are instructed to respond as quickly and accurately as possible, pushing a key labeled "yes" if the target is an English word, and a key labeled "no" otherwise. Error rates are low for young and elderly people alike, and the primary dependent variable is the response time required, from onset of the target, to make a correct lexical decision.

In the information-processing literature, three types of independent variables are often used to decouple the automatic and effortful components of priming in this task. Since each of our studies uses two or more of these methods, I will describe the logic of each now, referring to the outline in the lower half of Table 1. The first independent variable concerns the relation between the prime and target items presented on each trial. Typically, all studies of priming include at least two kinds of prime, *related primes* (e.g., the prime TREE before the target ELM) and *unrelated primes* (e.g., the prime VEGETABLE before the target ELM). The difference in response time between these two conditions provides a measure of overall *priming*. By including a third type of prime, a *neutral* item, some experimenters (e.g.,

Neely, 1977; Posner & Snyder, 1975) have argued that it is possible to divide the overall priming effect into a measure of facilitation (that is, speeding of response time), and a measure of inhibition, (that is, slowing of response time). Since automatic processes have unlimited capacity, they should yield facilitation, but not inhibition. In contrast, since effortful processes are limited in capacity, they lead to both facilitation and inhibition.

A second independent variable, Stimulus Onset Asynchrony or SOA, refers to the interval between onset of the prime and onset of the target. Studies with college students (e.g., Fischler & Goodman, 1978; Neely, 1977) have indicated that automatic priming occurs at SOA's as short as 40 msec, but typically decays within 700 msec. Effortful processes are usually effective only at SOA's of 500 msec or greater. Thus, at short SOA's facilitation without inhibition is expected, and since the priming is attributed solely to automatic effects, the Hasher and Zacks' hypothesis predicts no age differences in priming. In contrast, at long SOA's over 700 msec or so, both facilitation and inhibition are expected, since priming is due to effortful processes, and the Hasher and Zacks hypothesis would predict age differences in priming.

A third independent variable corresponds to the role of conscious control in effortful, but not automatic activation. It is possible to induce people to expect primes and targets to be either related or unrelated. This can be accomplished through specific instructions or through a high frequency of trials with a specific prime-target relation. If participants expect an unrelated target to follow a prime word, and if this results in priming of the unrelated item, then the priming can be attributed solely to effortful processes, since no automatic activation would spread between unrelated nodes. Experimental attempts to influence the subject's expectations should affect

only effortful, but not automatic priming. If effortful processes change with age, then the effects of variation of expectations should interact with age.

With these methods in mind we can consider the Pomona and then the Georgetown research. In both laboratories, the performance of young and elderly individuals of equivalent educational level and WAIS vocabulary scores is compared. The elderly participants range in age from 60 through 80 years. None is institutionalized and most have attended college. In all the studies, age-appropriate norms were used in constructing the stimuli, so age differences cannot be attributed to cohort differences in stimulus properties.

The Pomona study focused on the time course of effortful processes. This study varied the semantic relatedness of prime and target, the participants' expectations, and the SOA, using values of 410 and 1550 msec. Table 2 shows examples of the four expectancy by relatedness conditions. On each trial a category name served as the prime. Participants worked with only two such primes at a time and were instructed to expect a specific category of target words after each category name. For one category name (TREE in the example in Table 2), they were told to expect the target to be an instance of the same category. For the other category name (VEGETABLE in the example), they were told to expect the target to be an instance of a different category (ANIMAL in the example). For each category name, 80% of the word targets were in the expected category. Thus, in the example, TREE was followed by a member of the expected category TREE on 80% of the trials, and by a member of some other category on only 20% of the trials. VEGETABLE was followed by a member of the expected ANIMAL category on 80% of the trials, and by a member of the unexpected same category VEGETABLE on only 20% of the trials. Subjects were instructed to use the prime as a cue for the target and to shift their attention to the expected category.

After 100 trials with two category names as primes, the subject had a short break and then was given equivalent instructions for two other prime categories at a different SOA value.

The predicted effects of automatic and effortful processes in each prime-target condition and SOA are shown in Table 3. Facilitation which speeds response time is marked with a plus, and inhibition which slows response time is marked with a minus. At the 410 SOA, automatic processes can occur while the slower effortful processes are just beginning to have an effect. This SOA seems to be the minimum interval for shifting of attention to occur among young people, and thus effortfuul effects are not always obtained and are placed in parentheses in the table to indicate this. At the 1550 msec SOA, automatic priming has usually decayed and effortful processes have strong effects. To assess the effects of automatic priming at the 410 SOA, we subtract response time on same category trials from response time on different category trials. To assess the effects of effortful priming we subtract response time on expected target trials from that on unexpected target trials. The 410 SOA is particularly interesting, because if older adults require more time to shift attention, young but not older adults should show effortful effects here.

The mean response times for 32 young and 32 older adults are shown in Table 4. As predicted, the difference between same and different category primes (shown in the table as the automatic effect) decreased at the longer SOA, indicating a diminished effect of automatic processing. This effect did not interact with age, suggesting that there are no age differences in automatic activation at these SOA values. Also as predicted, the difference between expected and unexpected targets (shown in the table as the effortful effect) increased at the longer SOA, indicating a greater effect of effortful

processes as there is more time to shift attention. This effect did not interact with age. At the 410 SOA, for both age groups expected targets had a 10% decrease in response time compared with unexpected targets, and at the 1550 SOA a decrease of 15% for the young and 17% for the old. This is a most important finding since it indicates that the magnitude of the effortful effect was the same for young and elderly participants at both SOA's.

In summary, these data provide no evidence that older adults have a more limited ability to switch attention, or that they require more time than young adults to do so. Thus, the Pomona research reveals no age differences in the effortful components of semantic priming, nor in automatic priming at the 410 msec SOA. This age constancy canno+ be attributed to having tested a superior group of elderly people who show no cognitive deficits at all. In a subsequent incidental free recall test, these same elderly participants recalled significantly fewer of the lexical decision words than the young participants.

In contrast to the Pomona research, the Georgetown study focused on the time course of automatic activation. Table 5 shows examples of the five conditions each participant experienced. There are three types of trials on which the target is a word; related trials (e.g., CHURCH-STEEPLE), unrelated trials (e.g., DOG-STEEPLE), and neutral trials, in which the word BLANK always served as the prime. Expectations were not manipulated, and participants were told only that the prime and target would often be related and that this might help them speed their response to the target. Within each age group, SOA was varied between subjects, using values of 150, 450, and 1000 msec.

The data from a total of 108 subjects, 18 in each age by SOA group, are shown in Table 6. The major findings are seen most clearly by examining the columns labeled "Priming Effect," which was calculated by subtracting response

time on related from response time on unrelated trials.

The first important finding is that in agreement with the Pomona results, there are no age differences in priming at those SOA's which may involve effortful priming. If priming is reported as a percentage of the response time on unrelated trials, at 450 msec the young and elderly participants show 9% and 6% reductions, respectively, and at 1000 msec both groups show reductions of 7%.

The second major finding is that there is an age difference in priming at the 150 msec SOA, a duration at which only automatic priming occurs. Whereas the young group shows a significant priming effect of 34 msec or 6%, the elderly show a nonsignificant effect of 9 msec or 1%. We have also obtained this same finding of priming at 150 msec for young, but not older adults, in another study that differed from the present one in a number of ways.

It might appear that this failure to find priming among the elderly at the 150 msec SOA simply reflects a complete failure to process the brief prime. Indeed, the interstimulus interval needed to escape backward masking effects does increase with age (e.g., DiLollo, Arnett, & Kruk, 1982), and it might be argued that for older adults the target has simply masked the prime, rendering it undetectable. However, a number of observations argue against this as an explanation for the lack of priming. For one thing, research with college students indicates that semantic priming occurs even when subjects cannot detect or report the prime (e.g., deGroot, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983). Furthermore, in our experiment, it is clear that the elderly participants tested at the 150 msec SOA were able to detect and identify the prime on at least some trials. In an incidental recognition memory test that followed the lexical decision task, the elderly group tested at 150 msec showed significantly above chance recognition of the

prime items. In addition, those elderly individuals who had above chance recognition of the prime were no more likely to show priming than were their peers who revealed only chance recognition.

The age difference in priming at the 150 msec SOA is more likely due to an age-related slowing of one or both of two processes. First, there may be a slowing in the speed with which presentation of a stimulus word results in activation of the corresponding concept node in memory. Second, there may be a slowing in the rate at which activation spreads from the original node to surrounding semantically related nodes. Thus, at a 150 msec SOA, TREE may fail to prime ELM for the elderly person, either because it takes longer to activate the node for TREE, and/or because it takes activation longer to spread from TREE to ELM. We are now planning studies to differentiate between these two sources.

You may have noticed that I have not discussed the priming effect when broken down into its components of facilitation and inhibition. This breakdown, which is shown in the columns labeled "facilitation" and "inhibition" in Table 6, failed to show the predicted pattern of results. Several other aspects of the data (that I won't describe here) lead me to conclude that this unexpected pattern simply reflects the difficulty of finding a truly neutral prime condition, and one that is equally neutral across the lifespan. Deborah Burke at Pomona and Nancy Bowles at the Boston VA have encountered similar difficulties in aging studies, and deGroot, Thomassen, and Hudson (1982) have discussed the difficulty of finding a neutral prime in work with college students. The lesson to be learned from this and an earlier study in which we used a series of X's as the neutral prime, is that the inclusion of a neutral prime condition does not enable us to separate the automatic and effortful components of priming.

In conclusion, when the results from the Pomona and Georgetown research are combined, we have obtained two major findings. First, we find no evidence of age differences in the effortful components of semantic activation. The Pomona findings indicated that the elderly were just as likely as the young to use expectations, and that this was the case not only at the long SOA of 1550 msec, but also at the 410 SOA, where effortful effects are just beginning. This conclusion is also supported by the Georgetown results that revealed equal priming for young and elderly adults at SOA's of 450 and 1000 msec. Given the differences between the experiments, these similar findings indicate that this age constancy in effortful activation holds across different kinds of relatedness (i.e., the category relations used at Pomona and the word associations used at Georgetown) and different degrees of explicit instructions to subjects.

The second major finding is that there are age differences in the onset of automatic semantic priming. In two studies at Georgetown we have found that young adults consistently reveal priming at SOA's of 150 msec, but elderly adults do not. This slowing in the onset of priming could contribute to the difficulties some elderly people experience in understanding language under certain circumstances. For example, in normal conversation, speech is often unclear, but the semantic context automatically primes related concepts, helping people to deal with this ambiguity. Thus, any age-related slowing in the speed of semantic priming would make it difficult for the elderly person to comprehend rapid speech, particularly when coupled with the sensory deficits that accompany advancing age.

Ironically, then, the pattern of findings we have obtained is the reverse of what the Hasher and Zacks' (1979) hypothesis predicts. We have found an age difference in the onset of automatic, but not effortful priming. Much of

the earlier work supporting the Hasher and Zacks hypothesis comes from studies of retention. The present results suggest that consideration of a broader range of performance may necessitate revision of this influential theory.

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Tables to accompany Howard, D. V., & Burke, D. M. Aging and the Semantic Priming of Lexical Decisions. Paper presented as part of a symposium entitled "New Directions in Research on Automatic and Effortful Processing" at the meetings of the American Psychological Association, Anaheim, August 1983. A copy of the paper may be obtained from Darlene V. Howard, Department of Psychology, Georgetown University, Washington, D. C. 20057. This research was supported by grants to Darlene V. Howard and Deborah M. Burke from the National Institute on Aging.

Table 1

Assumed Characteristics and Expected Effects of Independent Variables on Automatic and Effortful Activation

Characteristics

	Capacity	Latency	Conscious Control
Automatic	unlimited	short	no
Effortful	limited	long	yes

Independent Variables

	Prime Type	Stimulus Onset Asynchrony	Expectations
Description	Vary relatedness of prime and target: Related, Unrelated, Neutral.	Vary time between onset of prime and target.	Vary instructions or probability of prime-target relatedness.
Automatic	Facilitation, but no inhibition, i.e., Related faster than Neutral. Neutral equals Unrelated.	Operates at SOA's of 40 to 700 msec.	Priming equal whether related or unrelated targets are expected.
Effortful	Facilitation and inhibition, i.e., Related faster than Neutral. Neutral faster than Unrelated.	Operates at SOA's of 500 msec and above.	Priming greater for expected than unexpected targets.

Table 2

Examples of the Four Expectancy by Relatedness Conditions in the Pomona Study

		Target Category Expectancy: Expected	Target Category Expectancy: Unexpected
Prime-Target Category Relatedness	Same (Related)	TREE-ELM 20 trials	VEGETABLE-SPINACH 5 trials
	Different (Unrelated)	VEGETABLE-DOG 20 trials	TREE-FOG 5 trials

Note: In this example the prime word was always either TREE or VEGETABLE. On 50 trials the target was a word and on 50 a nonword. Category names and instances were used equally often in each of the four prime-target conditions and in the two SOA's across subjects. Presentation order of the two SOA's was counterbalanced across subjects. For a given subject, no prime or target word used in one SOA was repeated in the other SOA.

Table 3

Predicted Effects of Automatic and Effortful Processes at each SOA and in each Expectancy by Relatedness Condition in the Pomona Study

	410 msec SOA: Expected	410 msec SOA: Unexpected	1550 msec SOA: Expected	1550 msec SOA: Unexpected
Same (Related)	Automatic + (Effortful +)	Automatic + (Effortful -)	Effortful +	Effortful -
Different (Unrelated)	(Effortful +)	(Effortful -)	Effortful +	Effortful -

Note: Speeding of response time is represented by + and slowing by -. Parentheses indicate that effortful effects are expected to be small and are not always found.

Table 4

Mean Lexical Decision Response Times (msec) for Young and Elderly Adults as a Function of Expectancy, Relatedness, and SOA in the Pomona Study

	410 msec SOA Expected	410 msec SOA Unexpected	410 msec SOA Automatic Effect	1550 msec SOA Expected	1550 msec SOA Unexpected	1550 msec SOA Automatic Effect
Young						
Same (Related)	615	682	43	630	723	17
Different (Unrelated)	657	726		627	760	
Effortful Effect	68			113		
Elderly						
Same (Related)	741	790	92	784	953	31
Different (Unrelated)	799	916		822	977	
Effortful Effect	83			162		

Note: Effortful Effect is Unexpected minus Expected RT, collapsing across Same and Different Conditions.
Automatic Effect is Different minus Same RT, collapsing across Unexpected and Expected Conditions.

Main Effects, $p < .02$
- Age
- SOA
- Expectancy
- Relatedness

Interactions, $p < .02$
- Expectancy x SOA
- Relatedness x SOA

Table 5

Examples of the Within-Subjects Conditions
in the Georgetown Study

Condition	Correct Response	Sample Prime-Target Pairs	Number of Trials Per Person
Related	yes	CHURCH-STEEPLE DOG-CAT	14
Neutral	yes	BLANK-STEEPLE BLANK-CAT	14
Unrelated	yes	DOG-STEEPLE CHURCH-CAT	14
Neutral-Nonword	no	BLANK-PELNY BLANK-FIRCH	14
Word-Nonword	no	STAIN-PELNY SEED-FIRCH	28

Note: No participant saw any prime or target word more than once, and across subjects each target word served equally often in each condition.

Table 6

Mean Response Times, Priming Effect, Facilitation, and Inhibition for Young and Elderly Adults as a Function of Prime-Target Relatedness and SOA in the Georgetown Study

	Young				Elderly			
SOA	Response Time	Priming Effect	Facilitation	Inhibition	Response Time	Priming Effect	Facilitation	Inhibition
150 msec								
Related	524		23**		724		-16	
Neutral	547	34**			708	9		
Unrelated	558			11	733			25
N-Nonword	647				800			
W-Nonword	642				809			
450 msec								
Related	494		37**		668		15	
Neutral	531	47**			683	45**		
Unrelated	541			10	713			30
N-Nonword	593				799			
W-Nonword	590				816			
1000 msec								
Related	478		24*		737		37	
Neutral	504	34**			774	57**		
Unrelated	512			8	794			20
N-Nonword	594				872			
W-Nonword	570				840			

*$p < .05$

**$p < .02$

Note: Priming Effect is Unrelated minus Related RT.
Facilitation is Neutral minus Related RT.
Inhibition is Unrelated minus Neutral RT.